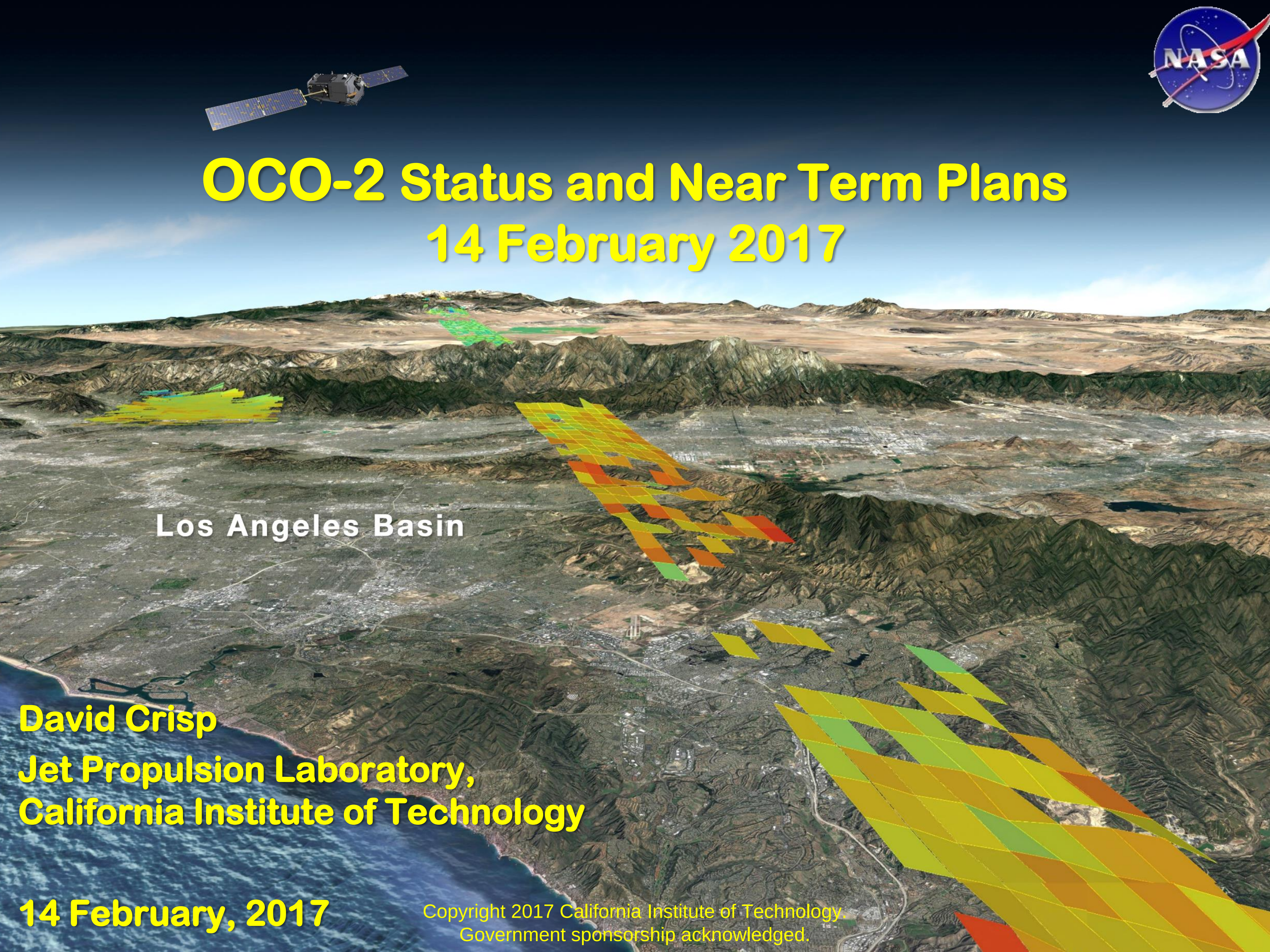
OCO-2 Status and Near Term Plans
14 February 2017



David Crisp

Jet Propulsion Laboratory,
California Institute of Technology

14 February, 2017

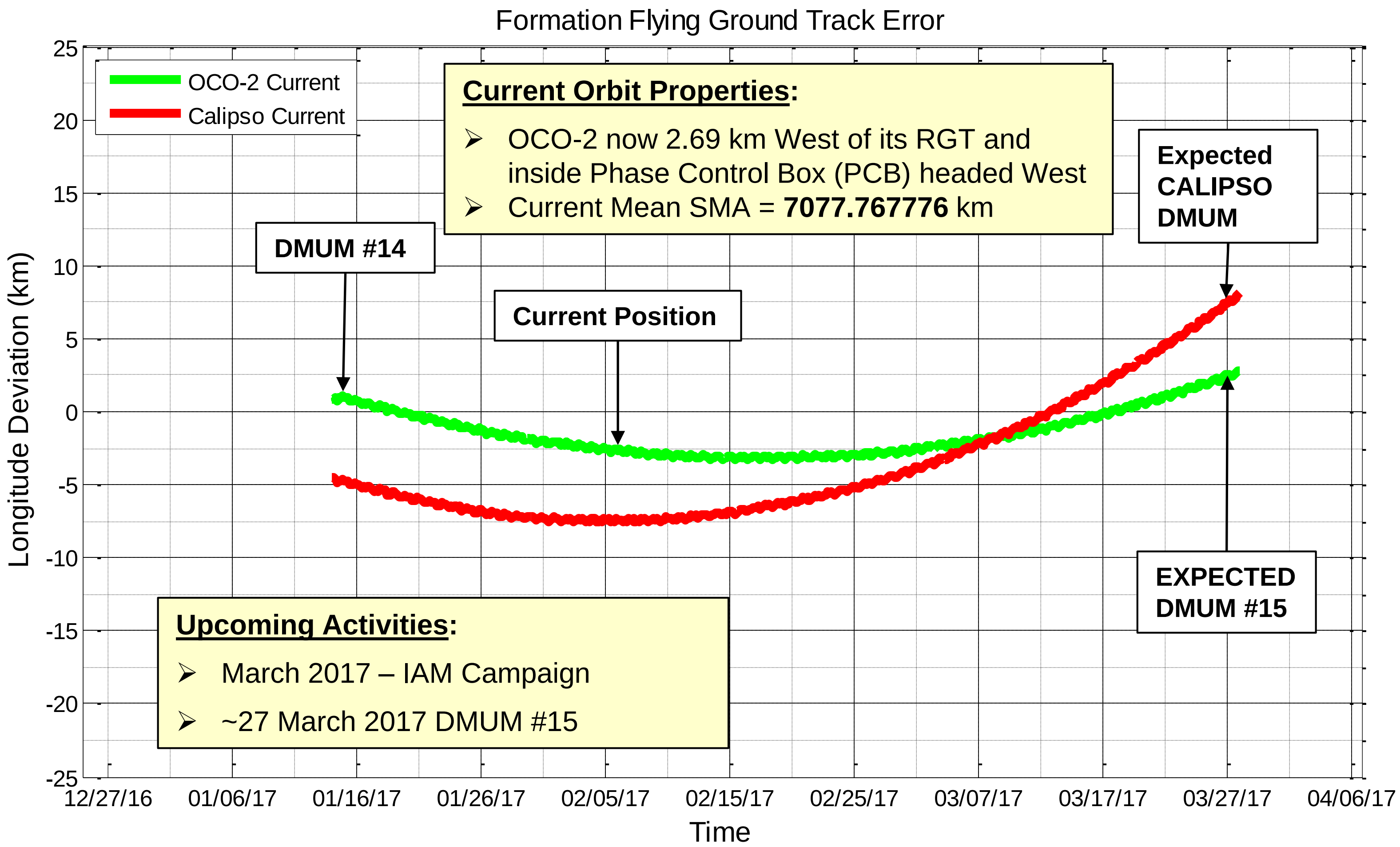
Overview

- OCO-2 Status and Near-Term Plans
- Senior Review Status
- Version 8 Progress and Plans
- Plans for the March 21-23 Science Team Meeting
- New Missions
  - TanSat Status
  - Introduction to the Gaofen-5 Mission
  - Introduction to the GeoCarb Mission
- Upcoming Meetings

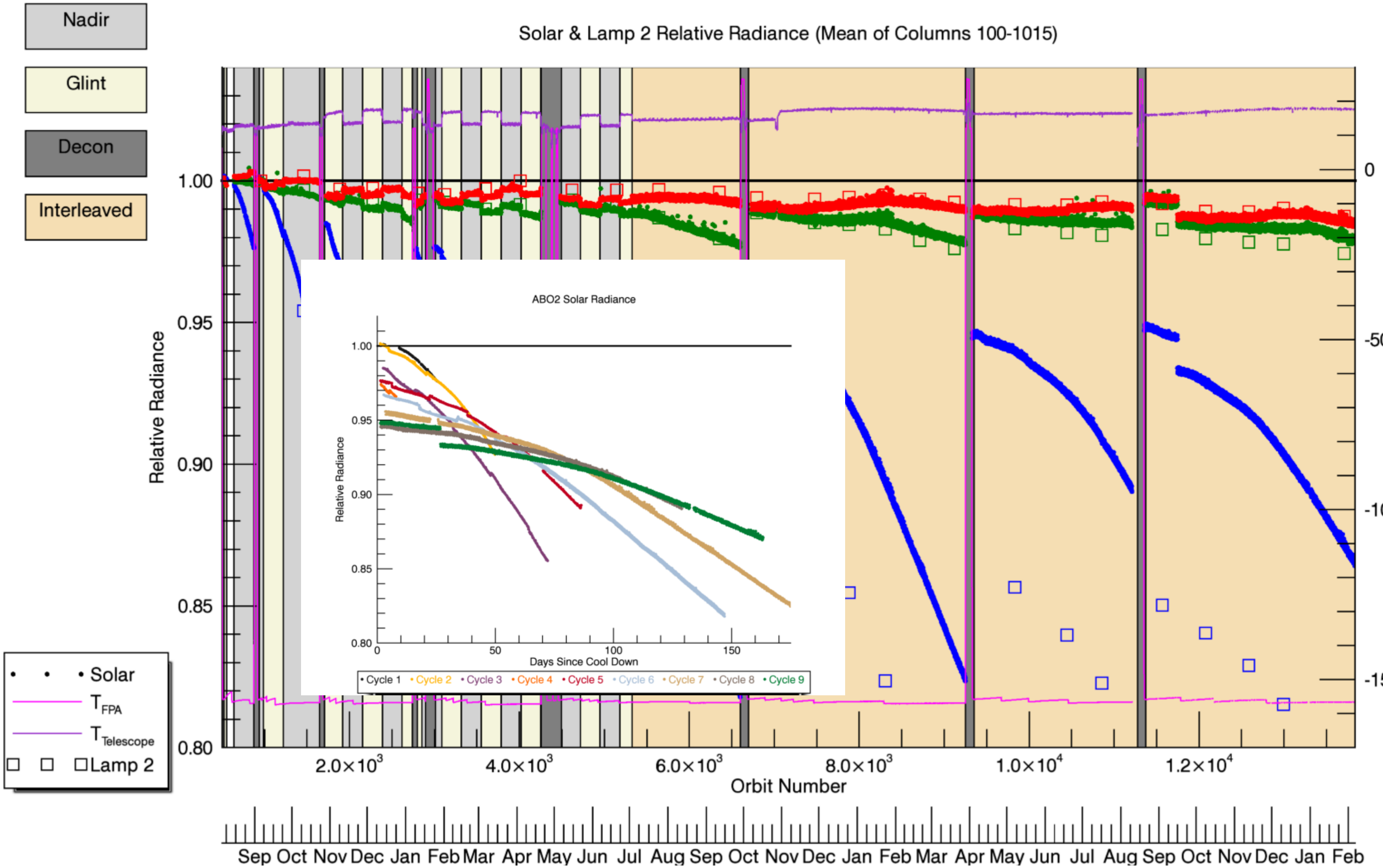
OCO-2 Status

- Observatory Status: Nominal
  - Last drag make-up maneuver (DMUM#14) - 13 January 2017
    - Next scheduled Drag Make-Up Maneuver – 27 March 2017
      - Part of 2017 inclination adjust maneuver campaign
- Instrument Status: Nominal
  - Next Decon planned for February 21 – March 1, 2017
- Science and Validation
  - Version 7r delivered through November 2016.
  - Continued testing of Version 8 build
    - Preliminary test suite completed, improvements ongoing
  - ACOS B7.3 production complete and documentation in process

OCO-2 and CALIPSO Ground Tracks



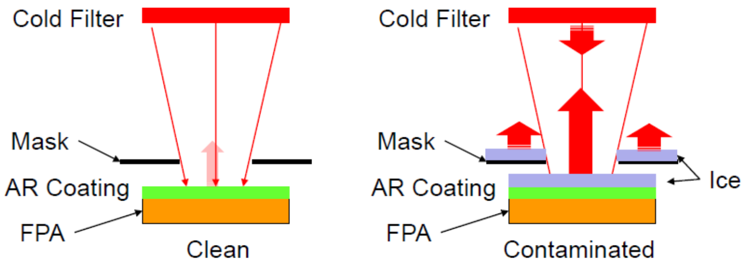
OCO-2 Instrument Trending

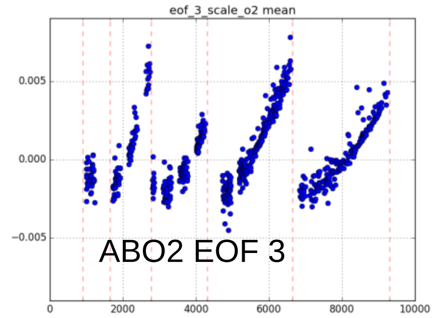


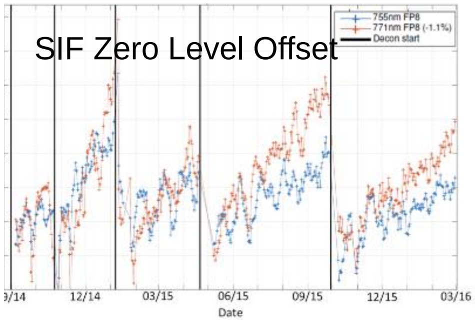
Ice accumulation rate on the ABO2 FPA continues to decrease over time.

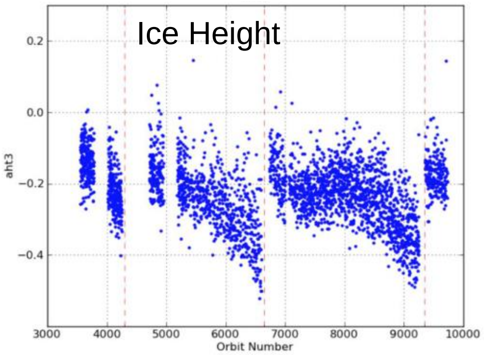
Instrument Calibration: Zero Level Offset

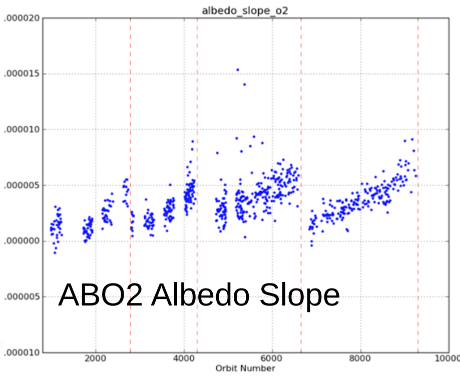
- The calibration team is characterizing the zero level offset (ZLO) associated with ice accumulation on the A-band (ABO2) focal plane array
- The ZLO introduces artifacts in EOFs and SIF, albedo, and aerosol retrievals
- Significant progress has been made in characterizing the ZLO and its changes with contamination level using Cal Lamps and Lunar observations





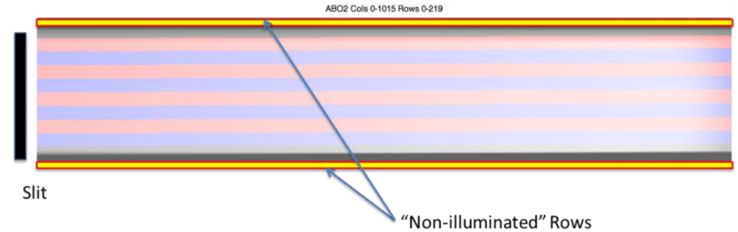


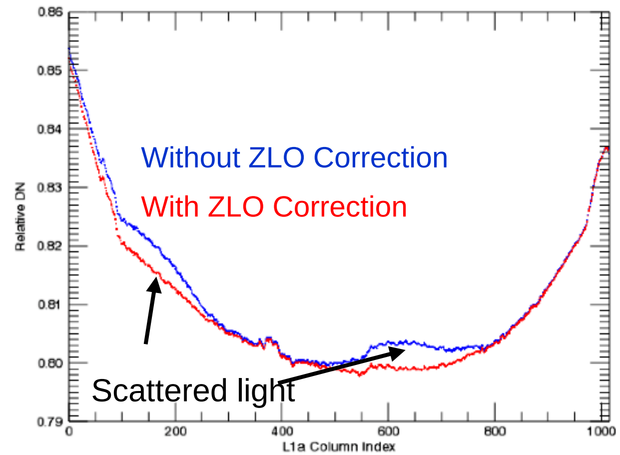




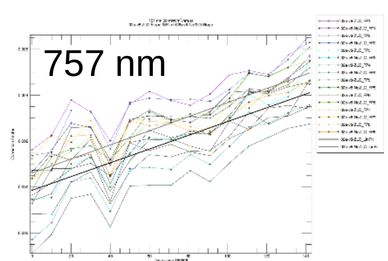
Zero Level Offset Correction

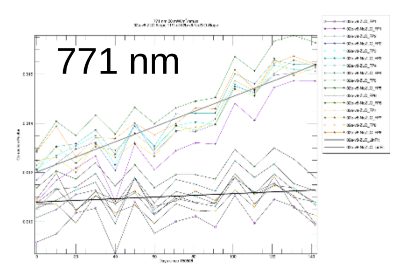
- A correction process has been developed to remove the ZLO from the L1B radiances
- This method is currently being tested for use in the Version 8 (v8) algorithm
- Preliminary tests show very good correction of 771 nm SIF offset, but produced little change in the (smaller) 757 nm SIF ZLO
- Next step – implement into standard L1B process, so that we can test full L2 algorithm





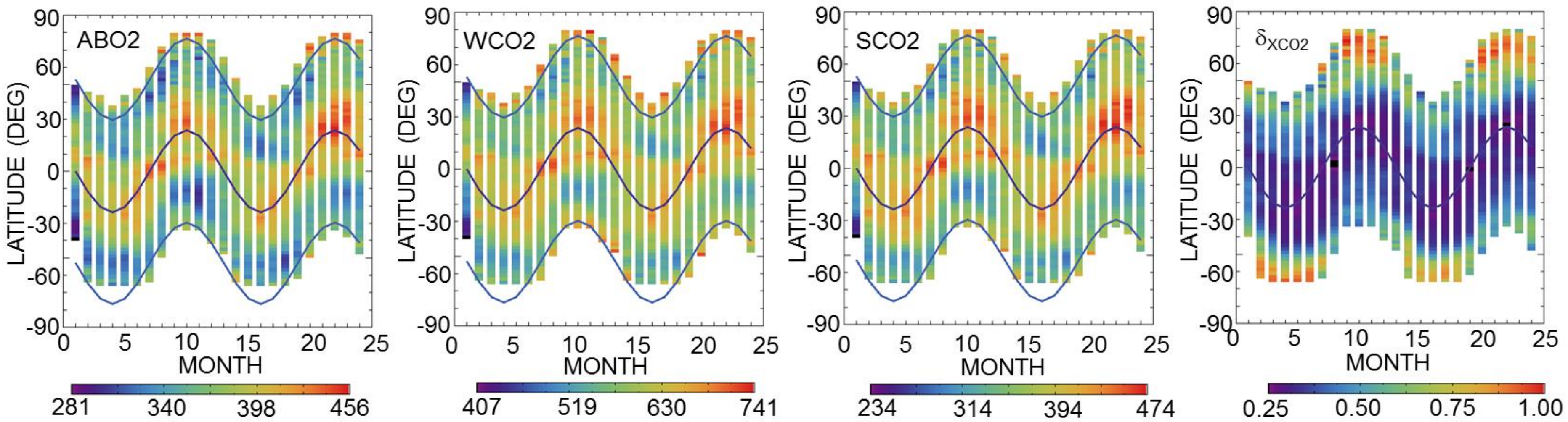
ZLO Testing





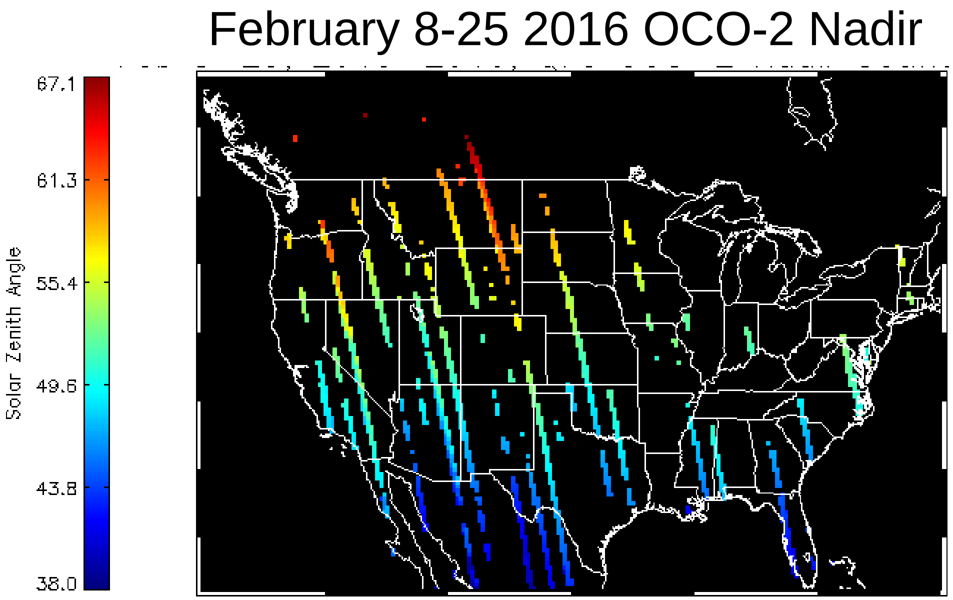
OCO-2 Glint Performance

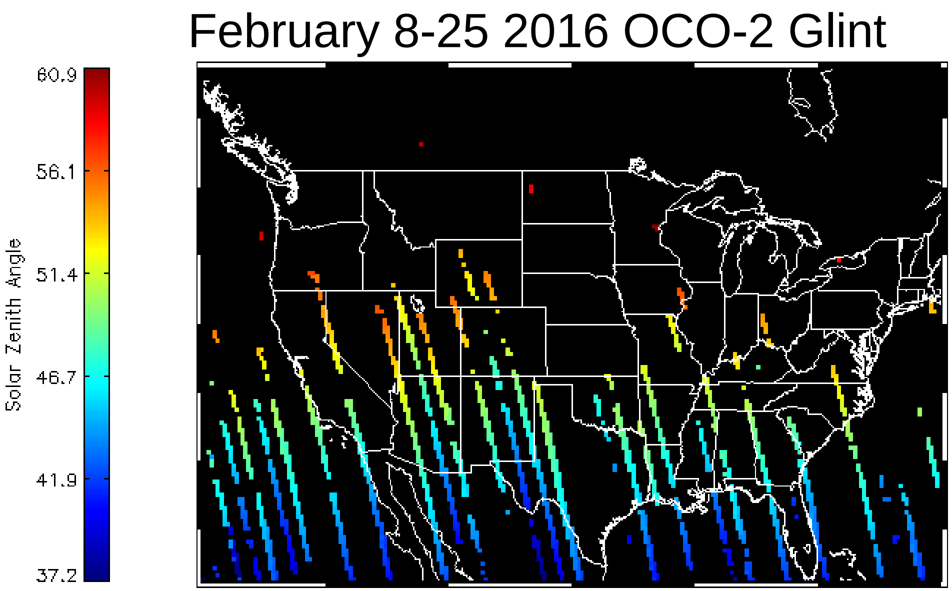
- Glint observations provide high SNR at solar zenith angles as high as 70°.
- The principle limit on the northern hemisphere latitude range is optically-thick clouds
- Clouds also limit the coverage of high latitudes in the southern hemisphere, but the v7 data product also includes a 65° S "Ice" cut-off that limits coverage at higher southern latitudes



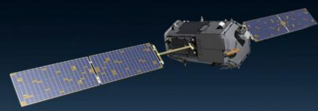
Latitude-time (Hovmoller) diagrams showing the single-sounding SNR and in the ABO2, WCO2, and SCO2 bands, and the resulting signal sounding random error in OCO-2 X_{CO2} for cloud-free glint observations (v7r Lite Files).

Nadir vs Glint Coverage over Land

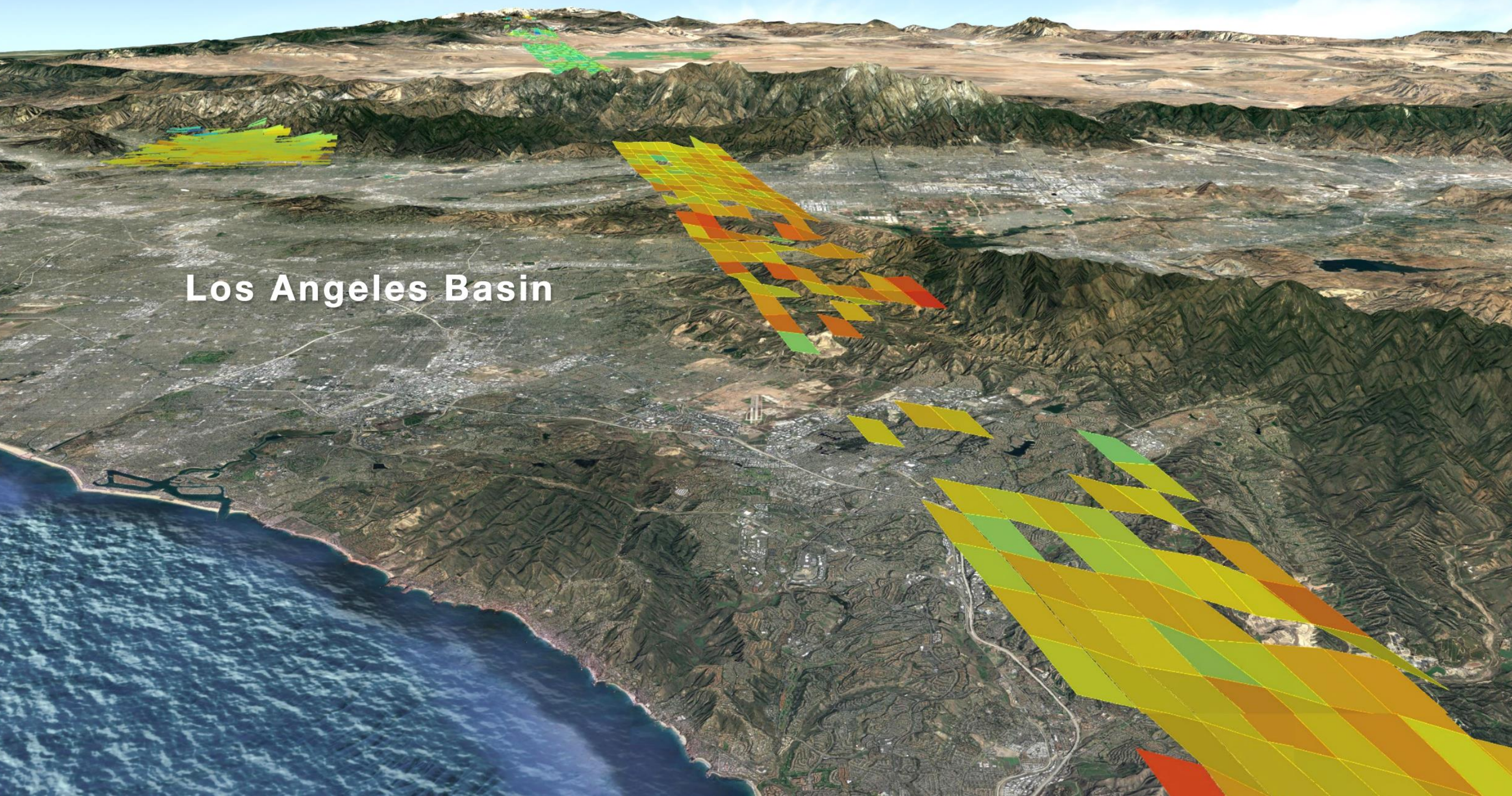




Nadir observations provide better coverage over continents, especially in the winter hemisphere due to the larger atmospheric air mass and larger probability of cloud contamination. The plots above show the coverage over North America for a 16-day repeat cycle in mid February (8-25) of 2016.

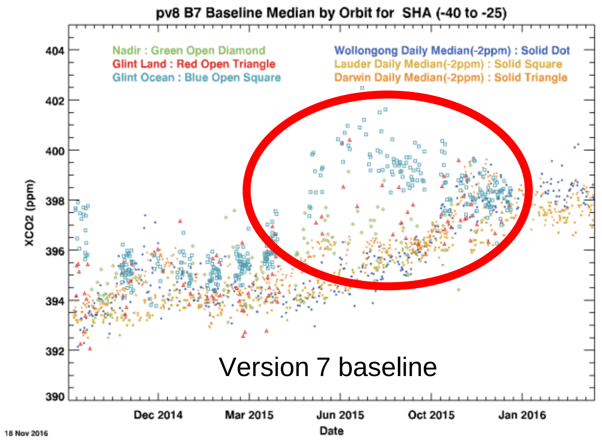


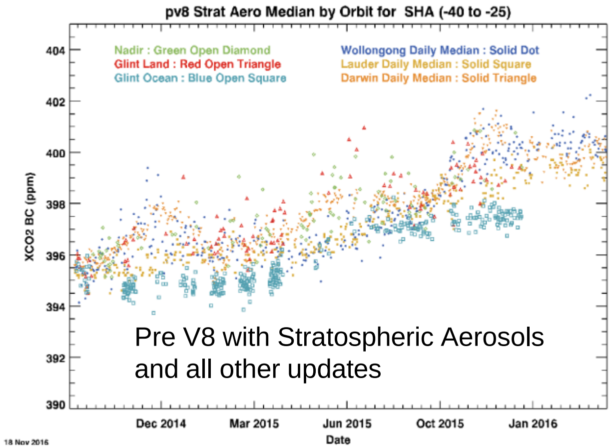
Version 8 Progress and Plans



Version 8 Testing

- Pre-Version 8 Tests completed
  - Calibration updates (slow degradation, etc.)
  - pre-V8 baseline: Revised L1B + ABSCO 5.0
  - updated surface BRDF
  - TCCON CO_2 prior
  - updated cirrus cloud prior
  - Stratospheric aerosols
  - MERRA-2 vs ECMWF Met prior
  - Rescale SCO2 ABSCO
- Tests to go
  - Daily aerosol prior, 65 S restriction removed
  - Zero level offset correction, Footprint bias, CO_2 Constraint

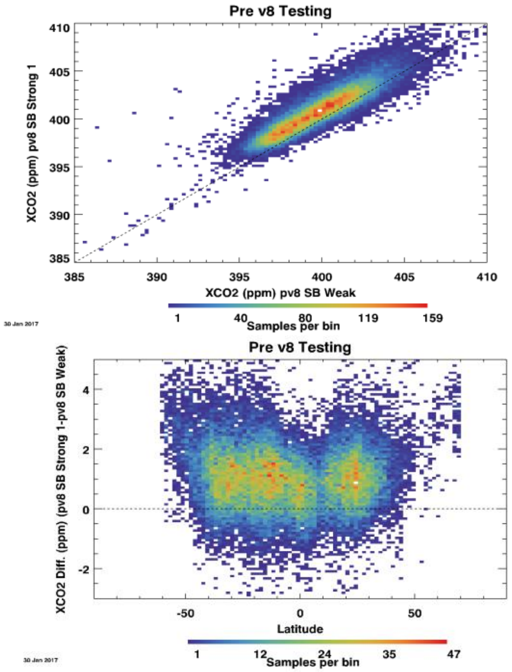




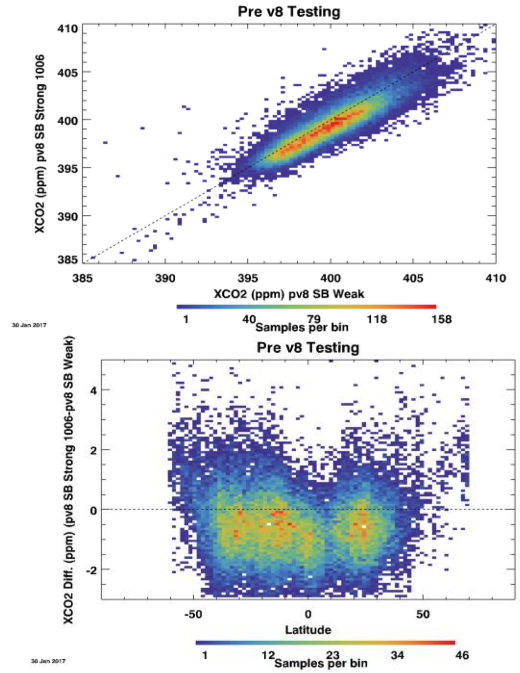
CO2 ABSCO Scaling

The ABSCO team has confidence in the scaling of the Weak CO_2 absorption cross sections, but there are larger uncertainties in the absolute scaling of the Strong CO_2 cross sections. We have therefore been running single-band tests to determine the scaling of the Strong CO_2 band needed to yield a good match to the Weak CO_2 band

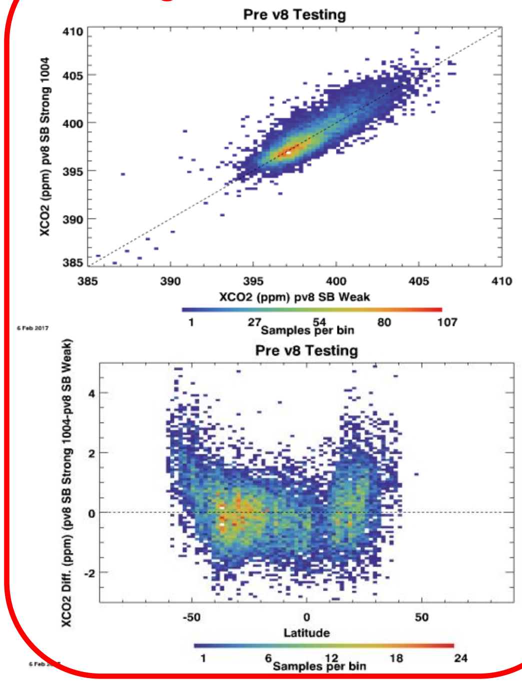
Strong CO2 scale = 1



Strong CO2 scale = 1.006

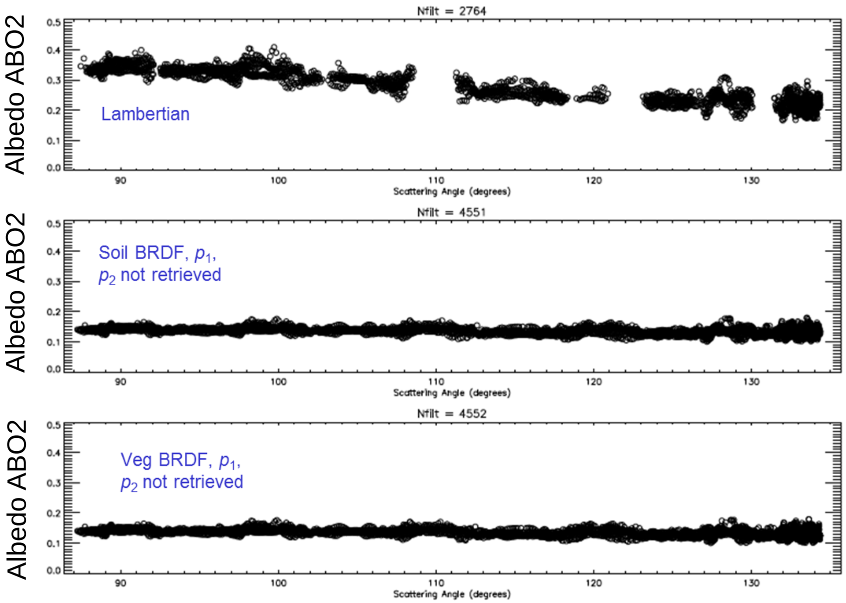


Strong CO2 scale = 1.004

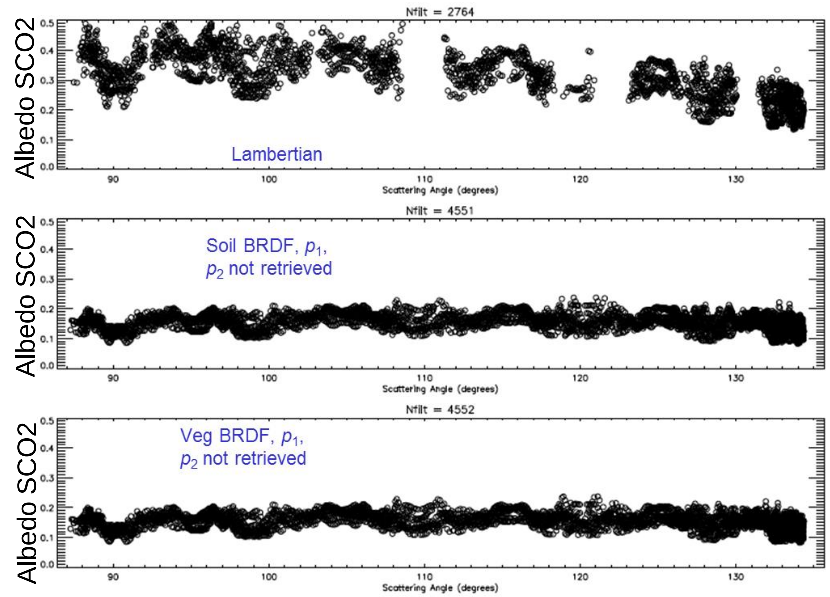


Consensus scaling is 1.004. Full three-band tests are in the works.

Improved BRDF Model Testing: Lamont Target, Orbit 1362 (1)



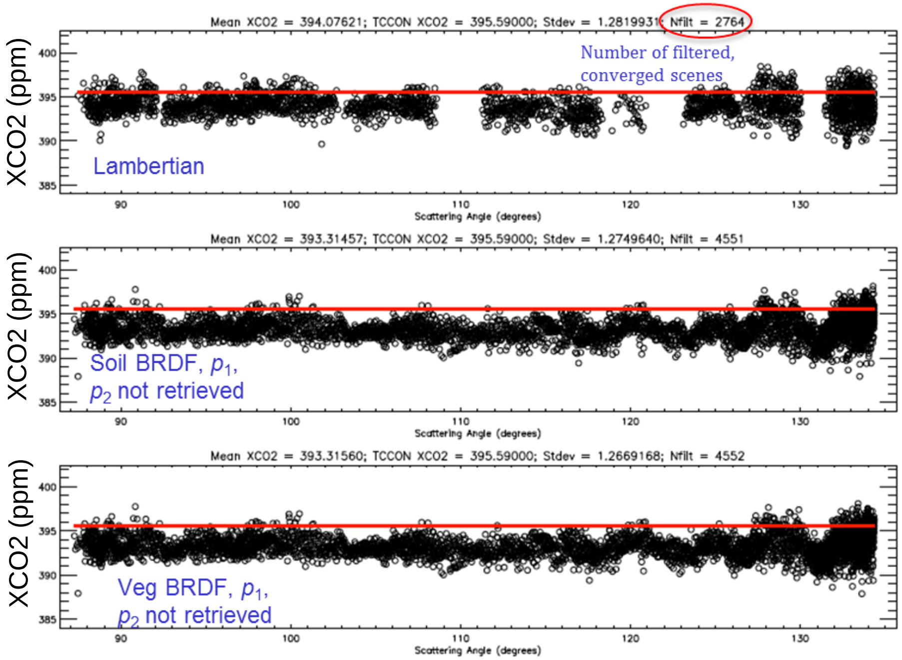
Surface reflectance retrievals in the O2 A-band using a Lambertian BRDF (top) are compared to those using a simplified Soil (middle) and Vegetation (bottom) BRDF



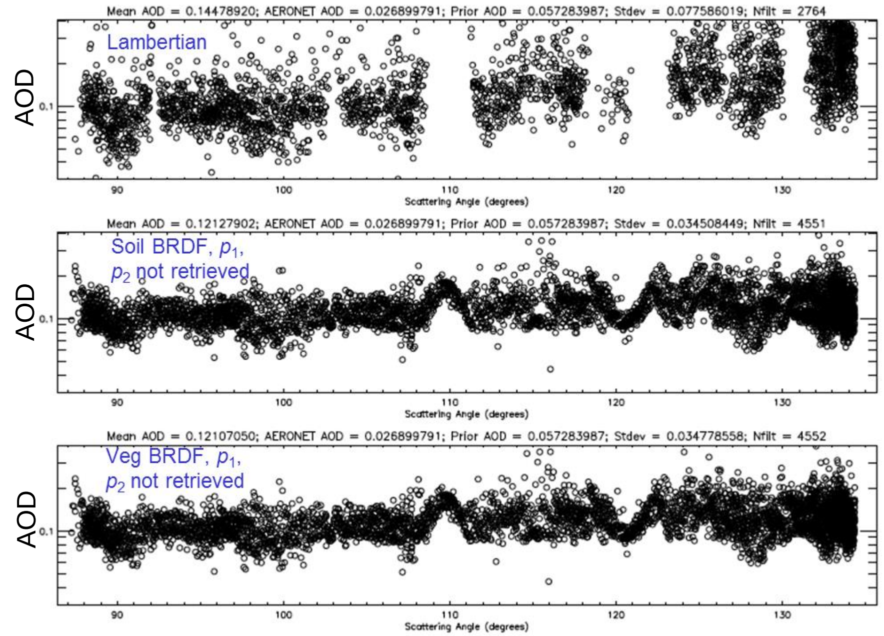
Surface reflectance retrievals in the Strong CO2 band using a Lambertian BRDF (top) are compared to those using a simplified Soil (middle) and Vegetation (bottom) BRDF

Both the simplified Soil and Vegetation BRDF functions reduce the scatter and systematic, observation-angle-dependence of the surface reflectance when compared to the current Lambertian surface albedo.

Improved BRDF Model Testing: Lamont Target, Orbit 1362 (2)



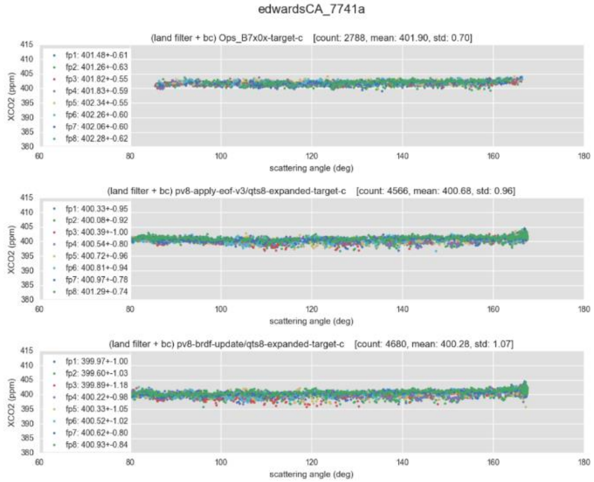
XCO2 retrievals using a Lambertian BRDF (top) are compared to those using a simplified Soil (middle) and Vegetation (bottom) BRDF



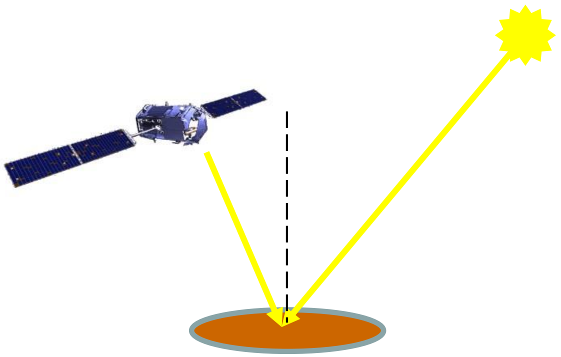
Aerosol optical depth retrievals using a Lambertian BRDF (top) are compared to those using a simplified Soil (middle) and Vegetation (bottom) BRDF.

Both the simplified Soil and Vegetation BRDF functions reduce the scatter in aerosol optical depth retrievals and increase the yields for X_{CO2} when compared to the current (v7/7r) Lambertian surface albedo.

Outstanding Issues with Non-Lambertian BRDF



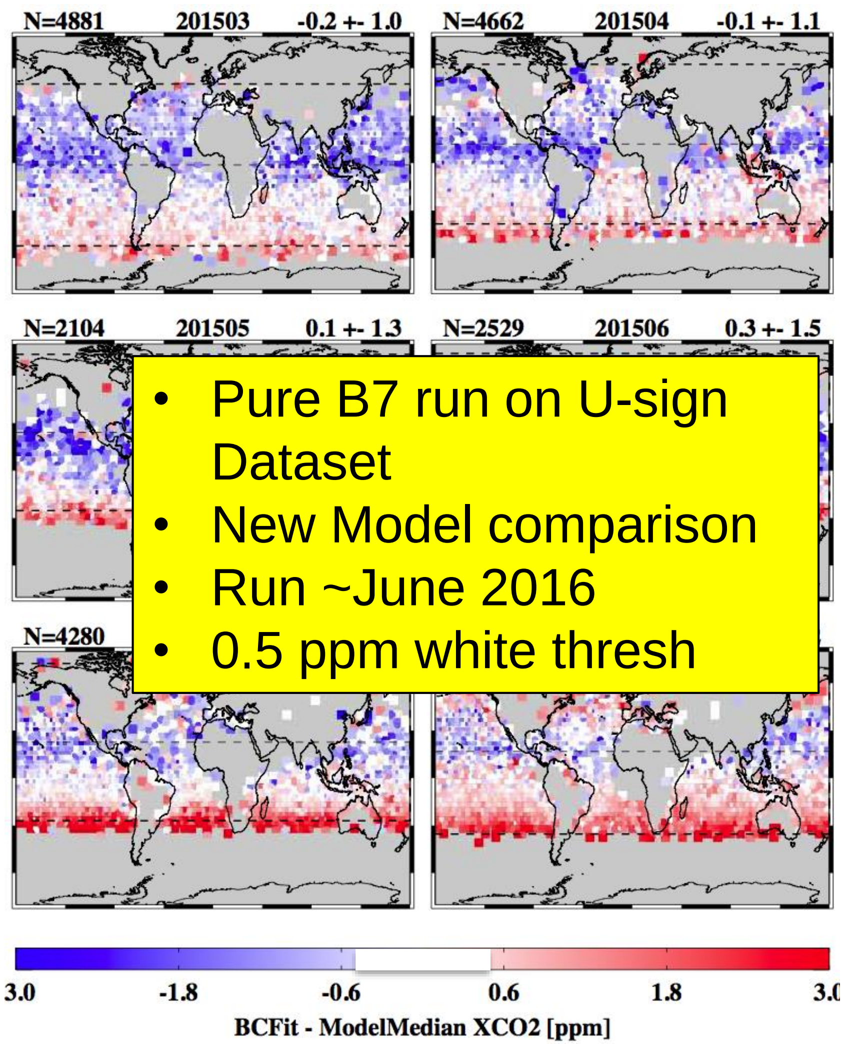
- While the non-Lambertian BRDF usually reduces the viewing angle dependent biases in the retrieved surface reflectance, aerosol optical depth,
  - It does not significantly change the XCO2 bias
  - There was some concern that it increased the scatter in XCO2, but this appears to be an issue with the pv8 baseline
- The non-Lambertian BRDF does not significantly reduce the observed slope and/or topographic dependent biases seen in target observations over Lauder
  - Simply too much to hope for??



- A final issue – what variable do we record in the file headers to represent the surface reflectance: **BRF at primary angle,** $BRF_0 = R(\theta_{\text{solar}}, \phi_{\text{solar}}; \theta_{\text{sensor}}, \phi_{\text{sensor}})$

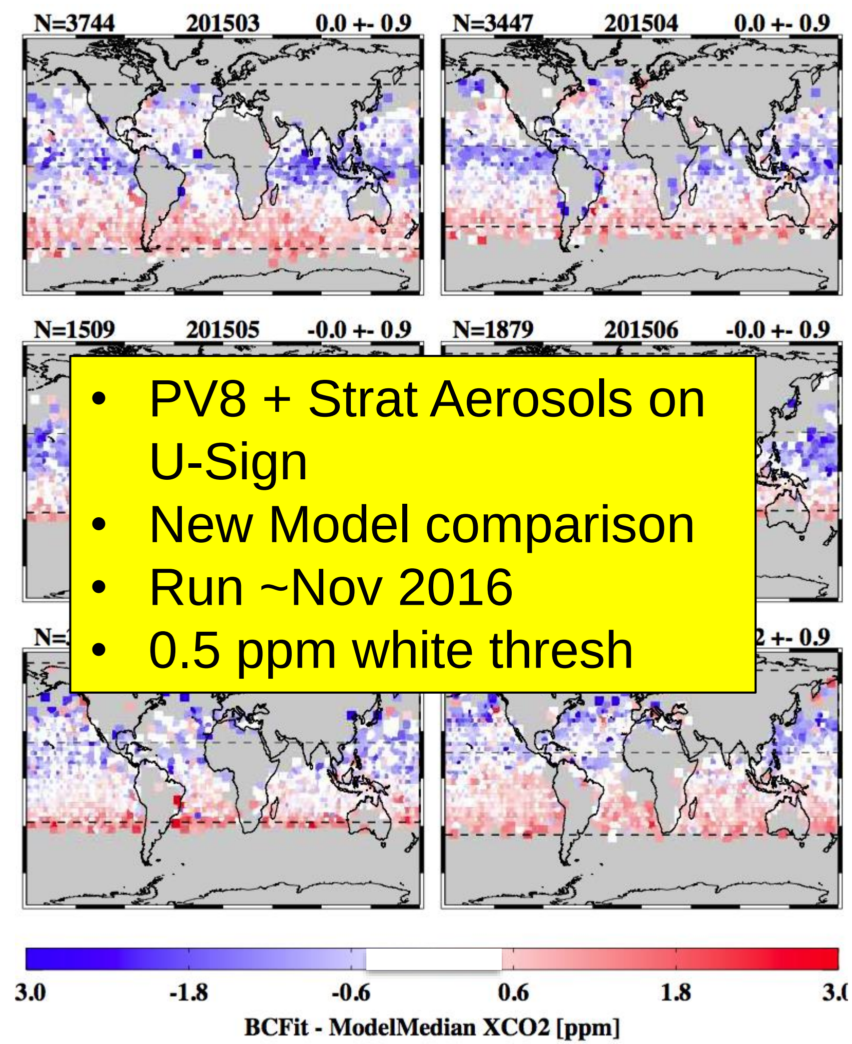
Stratospheric Aerosol

Without Strat Aerosols



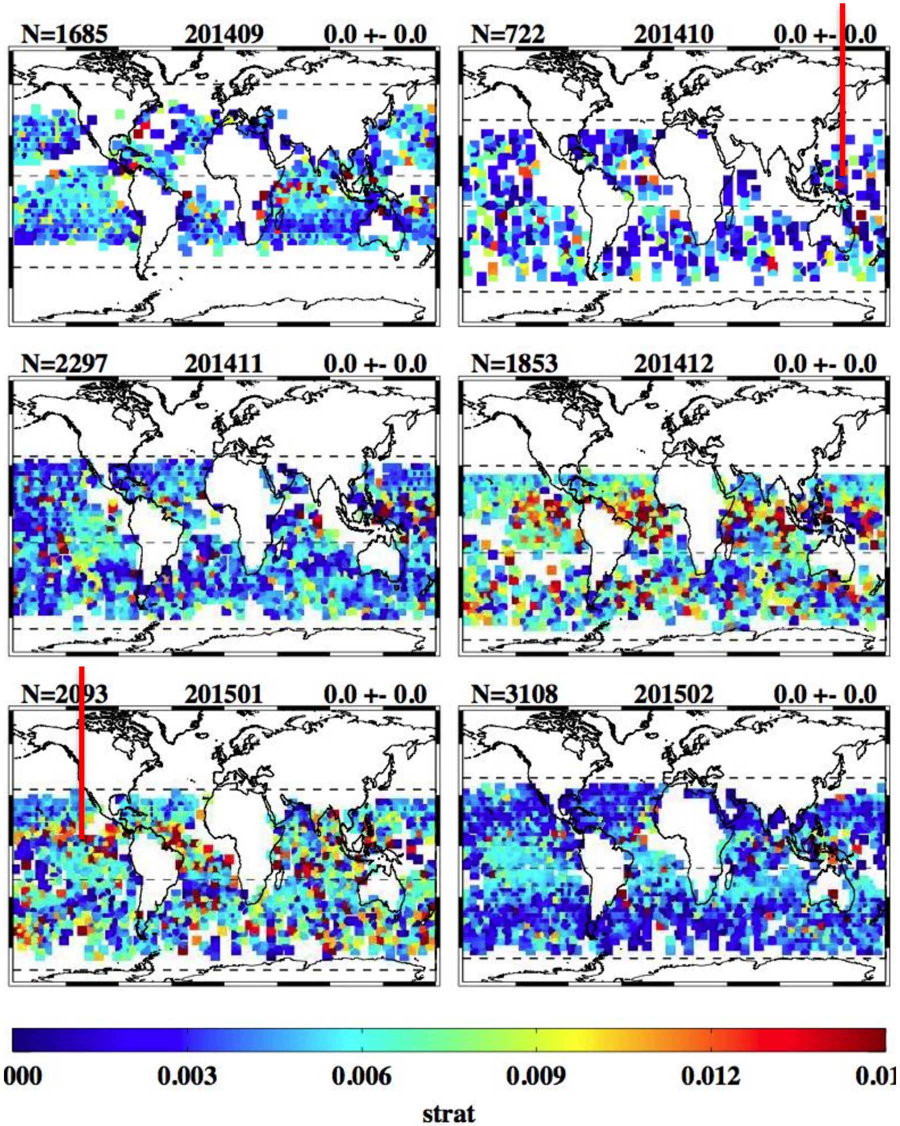
- Pure B7 run on U-sign Dataset
- New Model comparison
- Run ~June 2016
- 0.5 ppm white thresh

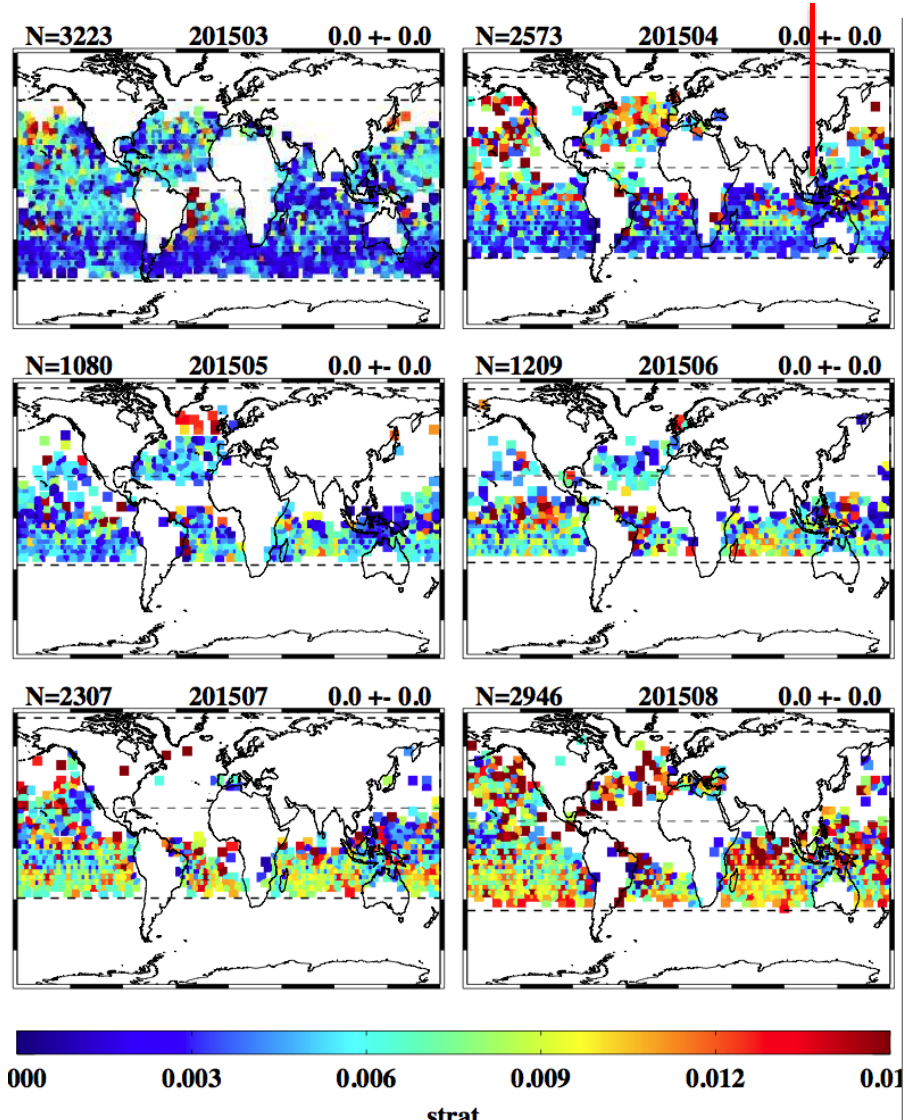
With Strat Aerosols



- PV8 + Strat Aerosols on U-Sign
- New Model comparison
- Run ~Nov 2016
- 0.5 ppm white thresh

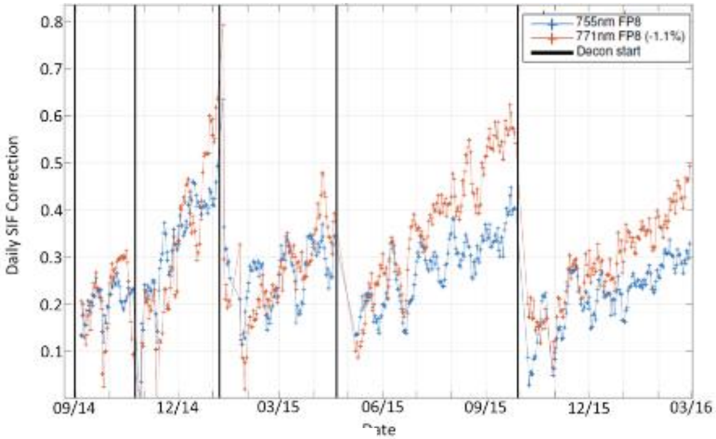
Retrieved Strat Aerosol Optical Depths



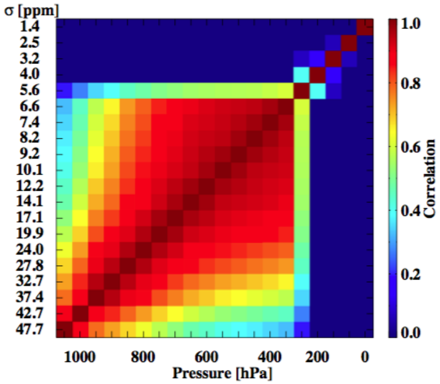


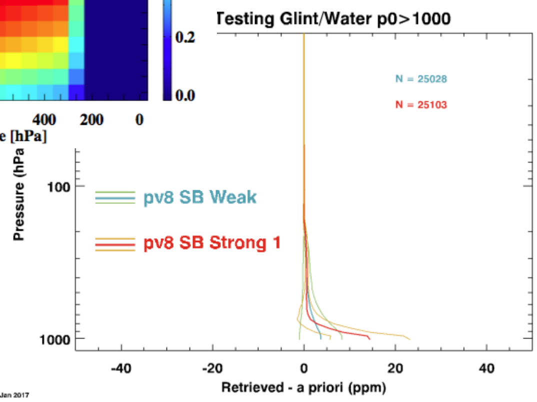
Ongoing V8 Tests

- Zero Level Offset (ZLO) correction produces little change in the SIF ZLO correction at 757 nm (blue), but substantially reduces the ZLO at 771 nm (red)



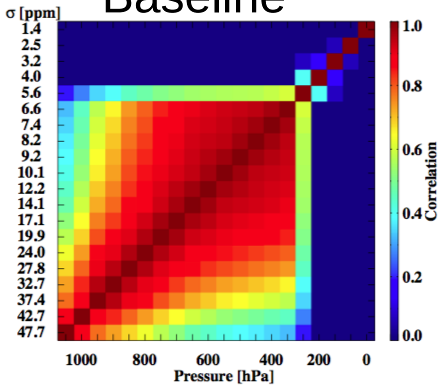
- CO2 a priori covariance tests
  - Issue: existing CO2 profiles often include an anomalous CO2 enhancement at the surface over land
    - This is the origin of the CO2_del_grad bias correction
    - This may be the result of uncertainties in the CO2 a priori covariance structure
  - These artifacts are amplified in v8



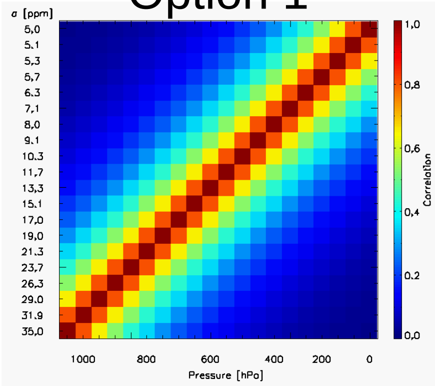


A priori Covariance Constraint Tests

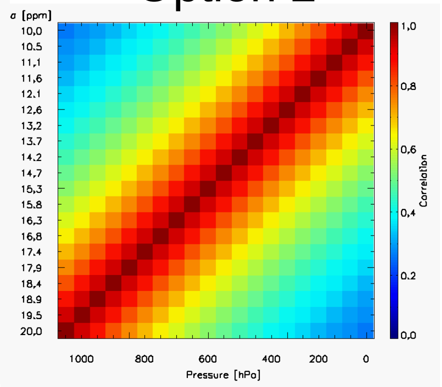
Baseline



Option 1

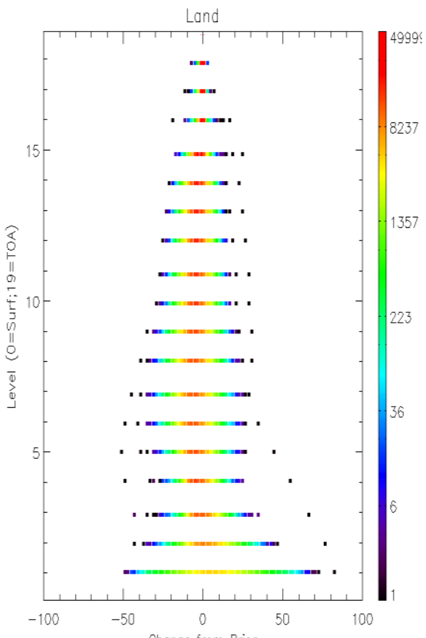


Option 2

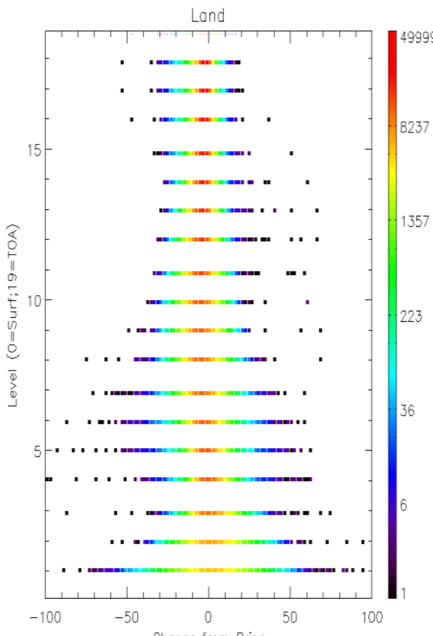


Options 1 and 2 produce more realistic CO_2 profiles, but introduce biases in the stratosphere

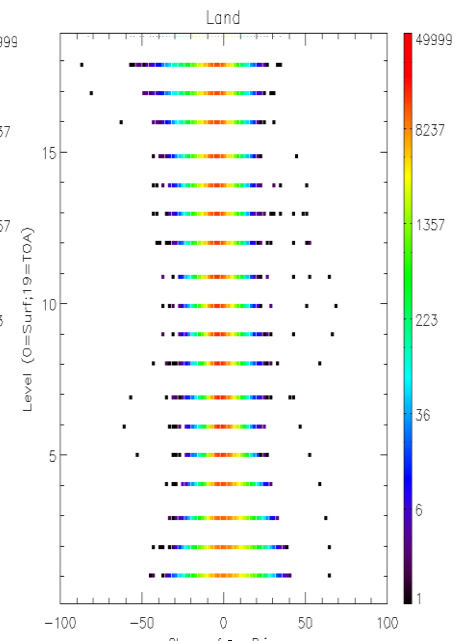
Options 1 and 2 require different bias corrections than the baseline option.



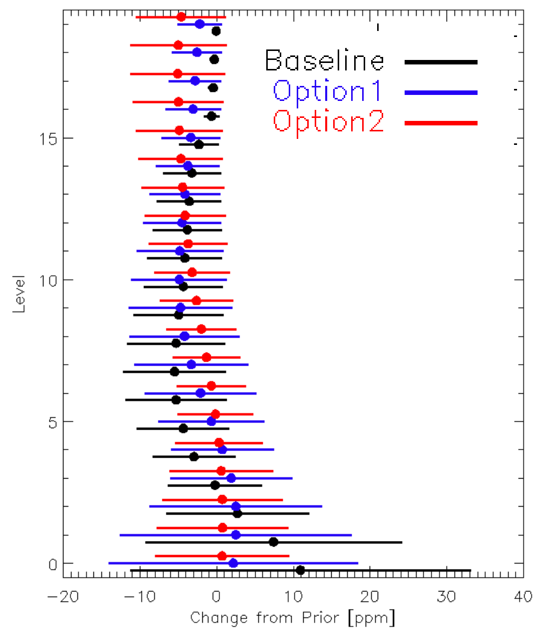
Baseline

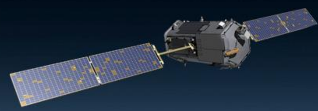


Option 1

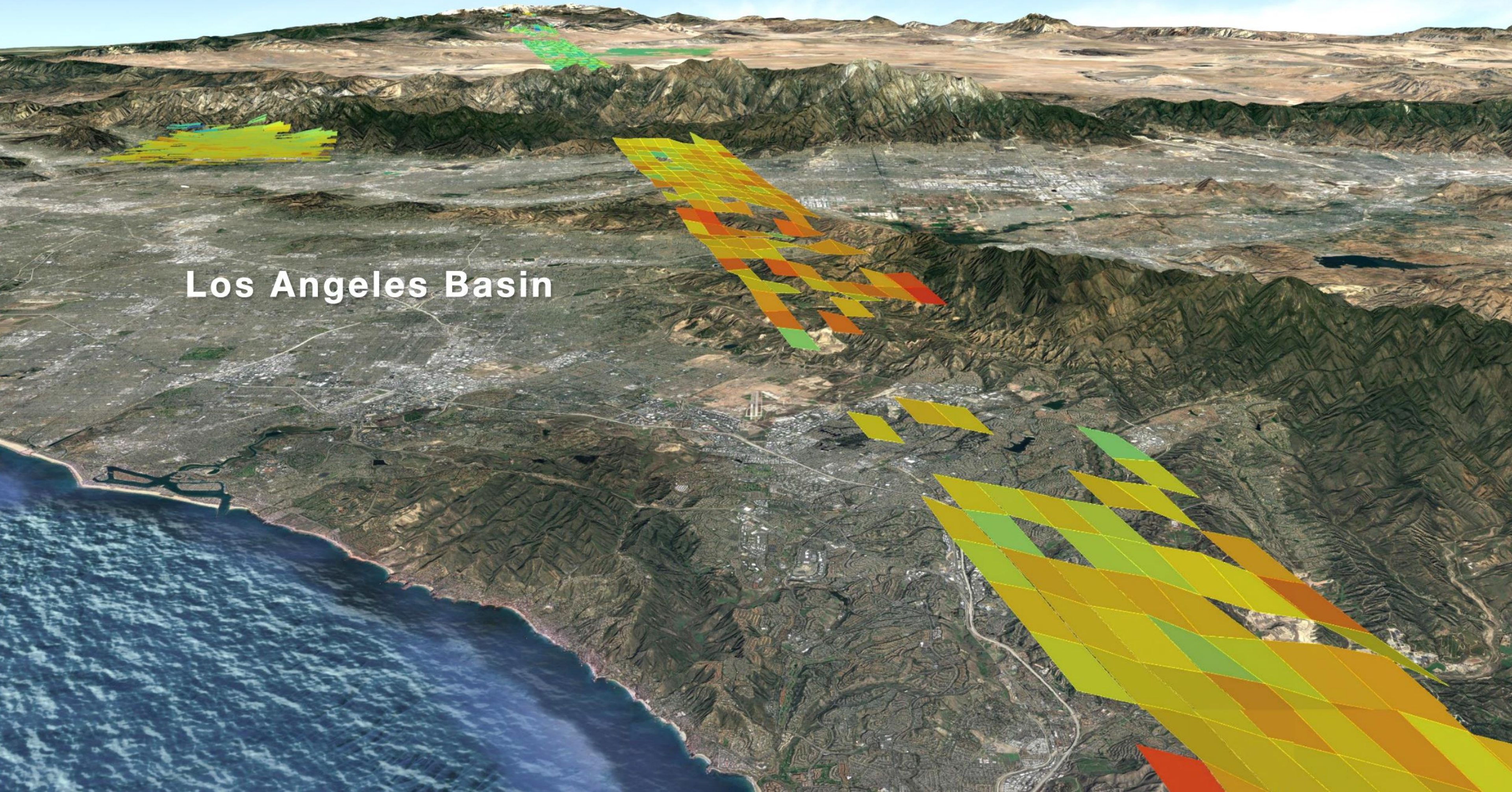


Option 2





Plans for the March 21-23 Science Team Meeting at Caltech



OCO-2 Science Team Meeting

- **Monday 20 March: Breakout Sessions**
  - Morning: Validation
  - Afternoon: Flux Inversion
- **Tuesday – Thursday 21-23 March Science Team Meeting**
  - Plenary Sessions
  - Speed Talks
  - Posters
  - Dinner Wednesday Night
- **Friday 24 March: Tag-on Meetings**

- **The Web Site is live!** https://sites.google.com/view/oco2stm0317/home

- **Register and sign up for speed talks and Wednesday dinner ASAP**

New Missions
TanSat Status
Introduction to Gaofen-5
Introduction to GeoCarb

TanSat Status

- TanSat was successfully launched on 22 December 2016
  - Launch included the TanSat satellite and 3 microsatellites
  - Initially inserted into a 1:30 PM sun-synchronous orbit 2.5 km above the A-Train. A-Train insertion still possible but plans are unknown
- Yi Liu attended the 9th GEOSS Asia Pacific Symposium and the AMS meeting
  - Reported that the in-orbit check-out was going as planned
  - First light spectra were acquired a day or two before the Jan 24 AMS talk
- They still plan to distribute the data, but the schedule is unknown

Term-1(2011-2015)
Measurement Goals
XCO2
1~4 ppmv
Monthly
500 x 500 km^2

Term-2(2013-2015)
Measurement Goals
CO2 Flux
Relative flux error
20%
Monthly
500 x 500 km^2

	O2-A	CO_2 weak	CO_2 Strong
Spectral Range (nm)	758-778	1594-1624	2041-2081
Spectral Resolution	0.044	0.12(0.081)	0.16(0.103)
SNR	360	250	180
Spatial Resolution	1km×2km, 2km×2km		
Swath	20km		

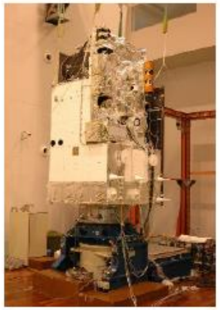
Yi Liu, 9th GEOSS Asia Pacific Symposium

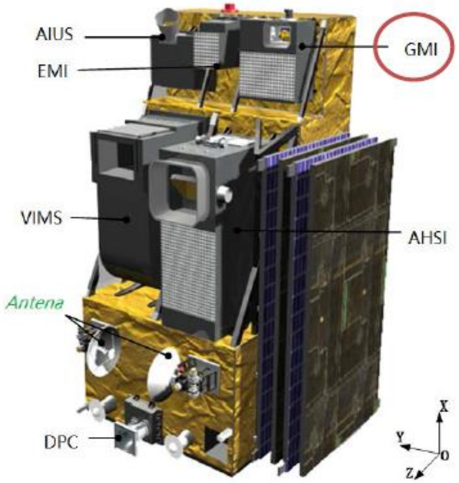
Gaofen 5 Satellite (GF-5)

- Yi Liu also confirmed that the GF-5 satellite will launch later this year, carrying the GMI instrument, which will measure CO_2 and CH_4 as well as a suite of other instruments

Orbital Type	Sun synchronous orbit
Orbital altitude	708 km
Local time	1：30

Sensors onboard GF-5
● Advanced Hyperspectral Imager (AHSI)
● Visual and Infrared Multispectral Sensor (VIMS)
● Greenhouse-gases Monitoring Instrument (GMI)
● Atmospheric Infrared Ultraspectral (AIUS)
● Environment Monitoring Instrument (EMI)
● Directional Polarization Camera（DPC）

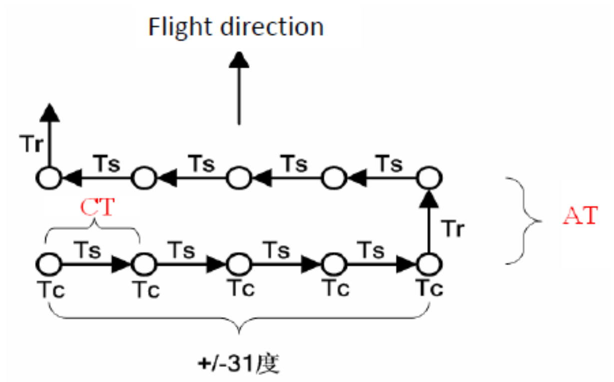




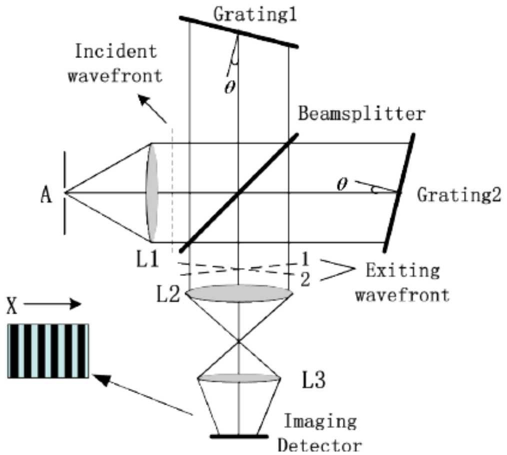
Yi Liu, 9th GEOSS Asia Pacific Symposium

GF-5 GMI Specifications

	technical parameters			
	O_2	CO_2	CH_4	CO_2
Central wavelength(um)	0.765	1.575	1.65	2.05
Band width(um)	0.759-0.769	1.568-1583	1.642-1.658	2.043-2.058
Spectral resolution	0.6cm^{-1}	0.27cm^{-1}		
SNR	300@ =30%		250@ =30%	
Radiation calibration	5% (relative, ~2%)			
Size	790mm (X) ×690mm (Y) ×575mm (Z)			
Field of view	14.6mrad IFOV<10.3km@708km			
Sample	5、7、9-points			
Observation mode	nadir(mainly)/glint			
Weight	109kg			
Power	120W			
Data transfer rate	30Mpbs			



Observation patterns	Along track direction AT (km)	Across-track direction CT (km)
1		
5	100	212
7	130	142
9	130	106



The specifications and observing strategy of the GF-5 GMI instrument are very similar to those of the GOSAT mission, but GMI uses a Spatial Heterodyne Spectrometer rather than an classical Michaelson Interferometer

Yi Liu, 9th GEOS Asia Pacific Symposium

The Earth Ventures GeoCarb Mission

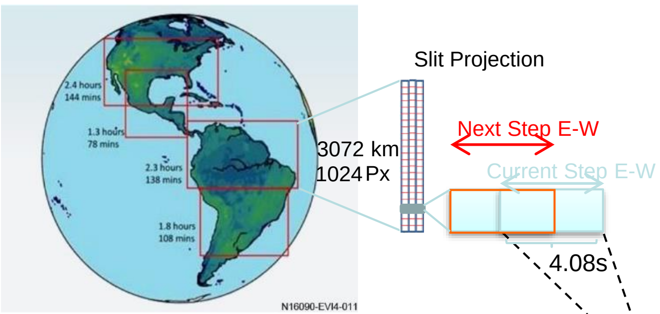
- NASA selected the Geostationary Carbon Cycle Observatory (GeoCarb) Project as the 2^{nd} Earth Ventures Mission
- GeoCarb is the first NASA satellite designed to collect spatially resolved observations of X_{CO2}, X_{CH4}, X_{CO} and solar induced chlorophyll fluorescence (SIF) from geostationary orbit (GEO)
- The Principal Investigator (PI) of the GeoCarb mission is Professor Berrien Moore of the University of Oklahoma
- Mission partners include
  - Lockheed Martin Advanced Technology Center in Palo Alto, CA
  - SES Government Solutions Company in Reston, Virginia
  - Colorado State University in Fort Collins, CO
  - NASA's Ames Research Center in Moffett Field, CA
  - Goddard Space Flight Center in Greenbelt, Maryland
  - Jet Propulsion Laboratory, Caltech, Pasadena, CA

GeoCarb Sampling

GeoCarb Sampling

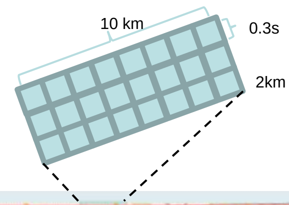
High Spatiotemporal Resolution
Daily/Sub-daily Revisits
Flexible Scanning Strategies

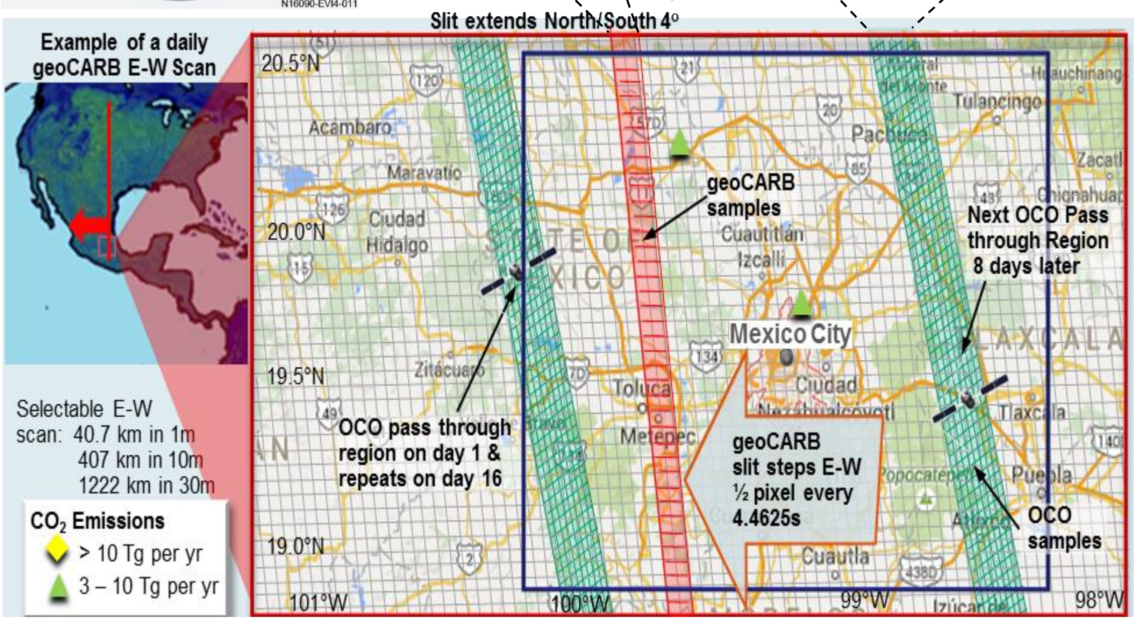
Fixed
FOV
Land only



OCO-2 Sampling

High Spatial Resolution Along Track
8 Footprints for Small Scale Variability
Global Land/Ocean Coverage
16 Day Revisit Cycle
Large Gaps Between Tracks





The geoCARB instrument will be hosted on a SES Government Solutions satellite in GEO orbit at 85° West longitude.

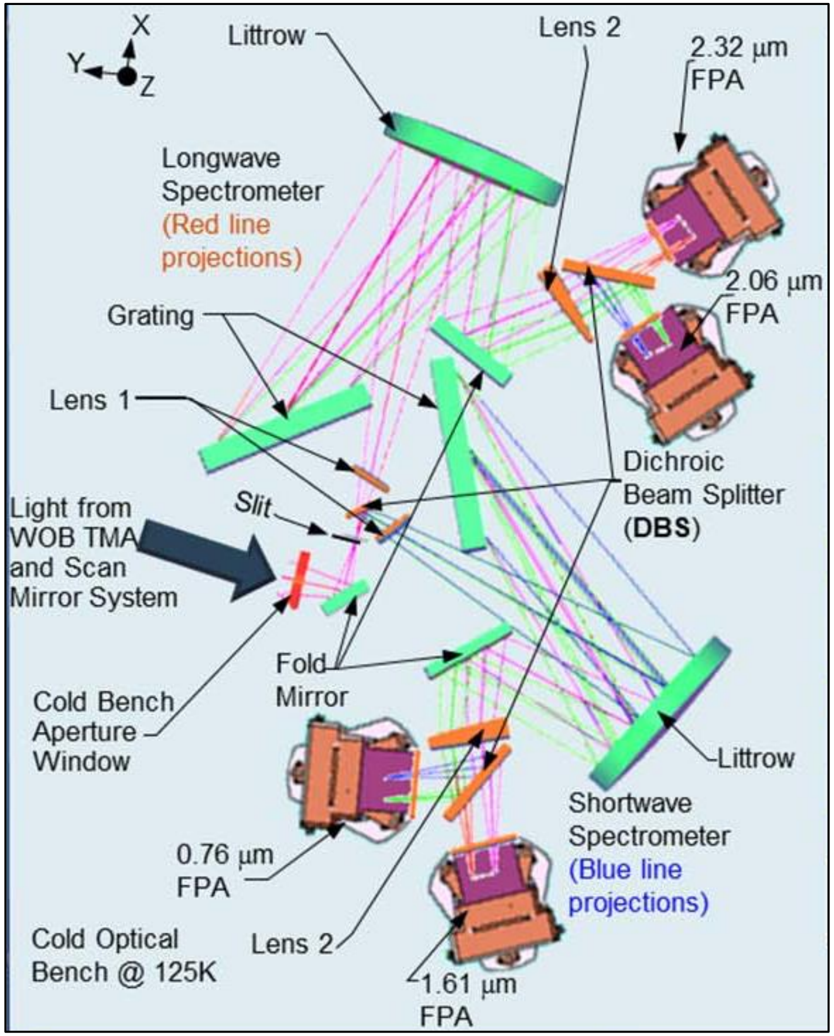
From this vantage point, the GeoCarb instrument will produce maps of the CO_2, CH_4, and CO concentrations and SIF at a spatial resolution of 5-10 km multiple times each day.

GeoCarb Instrument Design

GeoCarb employs a four channel grating spectrometer that measures reflected sunlight in four bands:

- **0.76 µm (O_2 and SIF)**
- **1.61 µm (CO_2)**
- **2.06 µm (CO_2)**
- **2.32 µm (CO and CH_4)**

Instrument model studies and OSSEs were performed to tie signal and noise characterizations and science objectives to realizable and scientifically useful



Evolving Carbon Measurement Capabilities

- TanSat Successfully Launched on 22 Dec 2016
- NASA Earth Ventures GeoCarb Selected
- CNES MicroCarb Approved for Implementation

Upcoming Activities

- 21-23 March: OCO-2 Science Team Meeting, Caltech, Pasadena, CA
- 27-30 March: North American Carbon Program, Bethesda, MD
- 10-13 April: GAW Symposium, WMO, Geneva
- 19-21 April: A-Train Symposium, Pasadena, CA
- 23-28 April: EGU, Vienna
- 20-25 May: JpGU, Chiba, Japan
- 6-8 June: IWGGMS, Helsinki
- 28-30 June: CEOS VC-AC, CNES HQ, Paris
- 6-11 August, AOGS, Singapore
- 21-25 August, ICDC10, Interlaken, Switzerland